(Nuclear) Power to the People

V.S. Arunachalam
Carnegie Mellon University, Pittsburgh PA 15213

Two growing and compelling perceptions, one political, and one managerial and technical, are overwhelming the many Atoms for Peace programs and retarding, if not halting their progress. First, the world has become a dangerous place because of the proliferation of nuclear weapons, especially in the hands of a few "wayward" nations, and second that nuclear reactors are inherently unsafe, prone to major and catastrophic accidents and there is no safe and proven method for disposing nuclear wastes. I have nothing new to contribute to Perception One that would assuage our concerns. And, frankly, we discussed this problem in achingly long sessions and don,t have any new suggestions to offer apart from advocating more of the same "control, sanctions and punishment" regimes. I don't think we discussed the reduction of weapon stockpiles by all nations, and some countries giving up the nuclear option altogether because of its irrelevance to their altered global roles and security concerns. This topic certainly merits a serious discussion in the Atoms for Peace framework.

Turning to the technical and managerial questions, the three major reactor accidents, Windscale, Three Mile Island and Chernobyl that altered our perceptions of reactor safety, were sobering. But they have also allowed us to learn a great deal about the domain of nuclear safety: its design, maintenance, and development. In particular, three areas of knowledge relevant to nuclear safety and nuclear power have grown impressively: Artificial Intelligence (AI), new materials and reactor designs, and the potential of nuclear power to meet the basic needs of human development such as providing safe drinking water and clean and efficient fuel for energy generation.

AI systems that emulate human intelligence and cognitive responses are now powerful, sophisticated, and heterogeneous. As a result, developments in all of computer science can be exploited in the search for nuclear safety. Sensors are now more sensitive, ruggedized and reliable, and can improve further with nanotechnologies; and the quality of machine initiated human-independent responses to prevent things going out of control are vastly different from 1957, 1979 or even 1986. Computational resources (bandwidth, memory, storage, multimedia) are no longer scarce. As a result, it is possible to build systems that are computationally extravagant. We must begin the process of deployment of such systems with all its heartaches and costs. With such systems, the management of a reactor,s operation will be spectacularly transformed. But none of this can happen till we begin development and deployment of such systems. This can begin, but only with political will, financial resources and managerial talent.

One could argue that, as in financial investments, past performance provides no guarantee for the future. Is it possible that such systems will have their own performance limitations? Of course. Does that mean that this is the wrong direction? No. Nothing ventured, nothing gained. AI, and some would say at last, has matured. The fear that humans can't always be trusted with instant and appropriate decision making in times of crisis is being replaced by renewed and growing confidence on machines.

Because of our past concerns, we have not invested enough for R&D in reactor designs and materials development. Apart from fast reactor technologies that have failed to mature in Japan or France, there are other new and enticing options to consider. New core and moderator designs enable optimum multiplication of neutrons. Composite fuels fabricated from uranium and plutonium compounds would push the reactor operations to higher temperatures, and thus to higher efficiencies. The compositions of such alloyed, dispersed or composite compounds could be so chosen that the fuel reprocessing stage could be eliminated for most of the reactors. Instead, the chain reaction would be in three continuous and overlapping stages: initial fissioning of U235 or Pu239, in situ conversion of fertile materials (U238, or Th232) into fissile ones, and the fissioning of newly produced Pu or U233. All these three reactions would be taking place inside a reactor. The spent fuels would not then contain any more plutonium and in this sense, the reactor should be classified as proliferation-resistant or plutonium burning. The lattice geometry and compositional mix of fuels should ensure that this technology could not be misappropriated for clandestine production of weapon grade materials.

I have cited the above options as examples of various promising avenues that exist for designing safe and more efficient reactors. All these need further pursuit to confirm their technical and commercial viability. But, as we expand our studies in these areas, I am confident that we can come up with more such proliferation-resistant and efficient designs that may also prove to be economical.

GDP and electricity are highly correlated, and the electricity consumption among countries shows a large divide. While developed western countries consume more than 8,000 kWh per person annually, developing countries, consumption of electricity is abysmal: around 350 kWh in India and around 800 kWh for China. If India and China were to emulate, say, the US, then the global carbon emission would increase to 14,400 million tons, almost 2.5 times the present production. And the CO2 concentration would jump to 400 parts per million. Nuclear power has virtually zero net carbon emissions. Various alternate technologies such as solar or wind-power have not lived up to the promise of large production of electric power. This is not to say that these options are irrelevant, especially in the developing countries context, but merely to underline the relevance of nuclear power for generating large amounts of electricity.

Nuclear power reactors have moved beyond being mere generators of electricity, and are now seen as producers of other basic needs such as drinking water, and hydrogen fuel for transport. Lack of safe and potable water in the developing world is seen as responsible for water becoming costly and unaffordable. A Tanzanian spends about 5.7% of her daily wages to procure 11.5 liters of water. The equivalent figure in the US is around 0.006%! Worse, millions become ill and many die in the developing world due to drinking polluted and bacteria-ridden water. Some analysts suggest that in many parts of the world reverse osmosis, powered by nuclear electricity is relevant not only for manufacturing water safe for drinking, but for irrigational needs too! One can extend a similar analysis for the production of hydrogen fuel as well. If India and China were to take the automobile route with just one car per family, based on the present reserves, the world would run out of fossil fuel reserves within a decade. Of course the aficionados of petroleum would argue that there are enough fossil reserves waiting to be explored and no fuel could be as competitive and efficient as petrol. There are many compelling reasons for exploring the nuclear-power hydrogen route: hydrogen is a clean fuel and the raw material for its production, viz., seawater, is equitably distributed all over the globe. It is also possible to design efficient prime mover systems that overcome the design limits of internal combustion engines, e.g., through fuel cells.

Safe disposal of nuclear wastes is a major concern and this has been flaunted as a critical impediment for pursuing the nuclear route. Newer encapsulation technologies and identification of appropriate sites that are geologically stable should assuage our concerns. Civil engineering structures safe for human habitat are now designed and built to withstand severe earthquakes, and these should lead to better and safer designs of waste disposal systems and sites.

The Atoms for Peace conferences were held when the Cold War was at its height. But it did not prevent scientists and policy makers from all countries of the world from meeting in Geneva, or in sharing their experience and knowledge. Even the chairman of the Conference was chosen from a developing country! Fifty years later, we have become more suspicious, less inclusive and appear to have erased President Eisenhower's vision of peace and prosperity unleashed by the power of atom being made available to all. Gated community of nations and suspicious neighbors can,t create a world free from disease, hunger and other basic deprivations. Is it now too late for us to change?

V.S. Arunachalam
Distinguished Service Professor
Departments of Engineering & Public Policy, Materials Science & Engineering
The Robotics Institute
Carnegie Mellon University, Pittsburgh PA 15213 USA
Tel: 412-268-2709
Fax: 412-268-3757
vsa@cmu.edu